Georgian Bay Air Quality Study 2001

Environmental Monitoring and Reporting Branch
Ontario Ministry of the Environment

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Executive Summary

From July 1 to 25, 2001, the Ministry of the Environment measured hourly pollutant concentrations along the shores of Georgian Bay, the Bruce Peninsula and on Manitoulin Island, using the state-of-the-art Mobile Air Quality Index (AQI) Unit.

Six pollutants were measured in this study: ozone (O_3), fine particulate matter (PM_{25}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and mercury (Hg).

During the study period, July 1 to July 25, 2001:

- There were no significant differences between the ozone concentrations measured by the Mobile AQI Unit and the fixed AQI site located in Parry Sound.
- Ozone measurements exceeded the provincial 1-hour ambient air quality criterion (AAQC) of 80 parts per billion (ppb) for 5 hours on July 21 at the Parry Sound AQI site, and for 3 hours on July 23 when the Mobile AQI Unit was at the Bruce Peninsula National Park.
- PM_{25} measurements at Dorset appeared to be more representative of levels in the Georgian Bay area than that of the Tiverton site located further to the south of the Georgian Bay area.
- The highest 24-hour average of PM_{25} was 31.1 micrograms per cubic metre ($\mu g/m^3$) measured at the Tiverton site on July 21.
- The maximum concentrations for NO_2, CO and Hg were significantly higher in the Toronto area than in the Georgian Bay area, reflecting the impact of urban sources of these pollutants.

During the Smog Season, May 1 to September 30, 2001:

- On average, the Parry Sound site recorded lower levels of O_3 than the Tiverton, Grand Bend and Long Point sites during the 2001 smog season, May 1 to September 30, 2001.
- On occasion, for example July 21, Parry Sound recorded higher maximum levels than other sites.
- The provincial AAQC for 1-hour average ozone levels was exceeded for at least one hour on 15 days during the 2001 smog season at Parry Sound compared to 16 days at Tiverton, 23 days at Grand Bend and 34 days at Long Point.
- There were 17 smog advisory days called during the 2001 smog season for the Tiverton and Parry Sound areas, 21 for the Grand Bend area and 22 for Long Point.
- Ozone levels typically decreased from south to north and southern areas were more often under smog advisories than in the north.

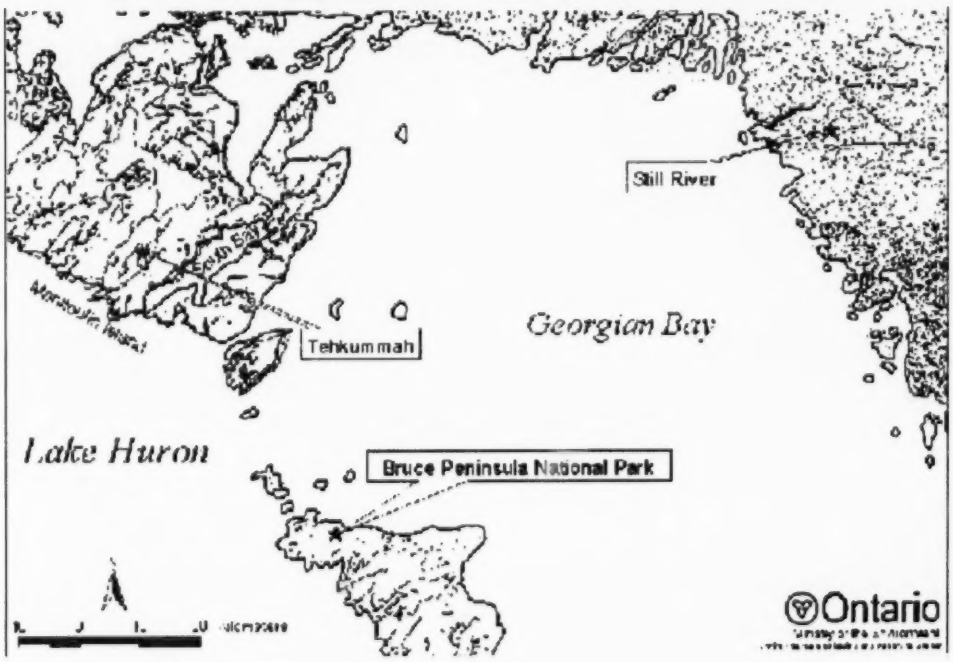
GEORGIAN BAY AIR QUALITY STUDY 2001

INTRODUCTION

In July 2000, the Ministry of the Environment measured hourly concentrations of smog-related pollutants at a number of sites around the shores of Georgian Bay using their state-of-the-art Mobile Air Quality Index (AQI) Unit. During the period of the study, hourly concentrations of pollutants monitored did not exceed their respective ambient air quality criterion (AAQC). The wet and cool weather conditions, experienced during the summer of 2000, were not conducive to the production of very high levels of smog.

As a result, it was recommended that a second study of the Georgian Bay area be conducted during the summer of 2001 where the Mobile AQI Unit could spend longer periods of time at each location to monitor air quality under a variety of meteorological conditions. A second study was conducted from July 1 to July 25, 2001 around the shores of Georgian Bay. The Mobile AQI Unit was located at Tehkummah, Manitoulin Island from July 1 to 6, Still River from July 6 to 13, and the Bruce Peninsula National Park from July 13 to 25 (as shown in Figure 1).

Figure 1: Mobile AQI Unit Locations for Georgian Bay Study, 2001

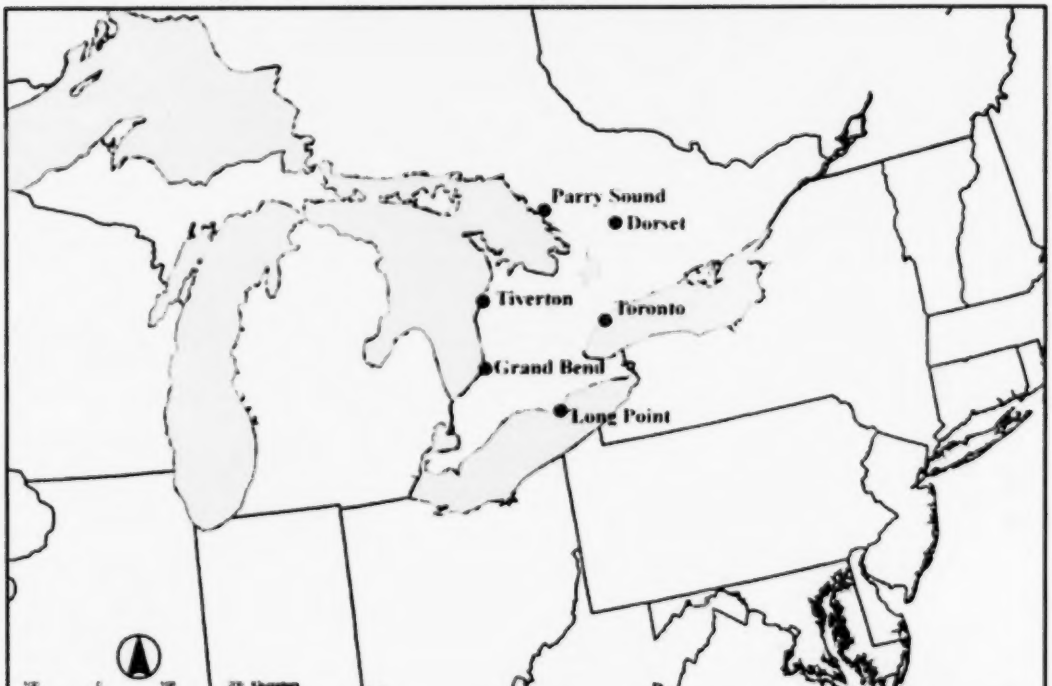


It was also recommended for monitoring to take place during smog episodes to determine more conclusively how the Georgian Bay area is affected during such periods, and to ascertain how trans-boundary pollution and long-range transport of pollution impact the Georgian Bay area. Therefore, in May 2001, the Ministry of the Environment established a fixed AQI station in Parry Sound to monitor ozone (O_3), one of the major components of smog.

To determine whether the Parry Sound site provides a true representation of ozone concentrations to which residents of the Georgian Bay area are exposed, daily maximum average 1-hour ozone concentrations measured by the Mobile AQI Unit were compared with those measured at the fixed Parry Sound site. Also during the same study period, fine particulate matter ($PM_{2.5}$) measurements made by the Mobile AQI Unit were compared with measurements made at the Dorset and Tiverton sites. In addition, concentrations of ozone, $PM_{2.5}$, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and mercury (Hg) measured by the Mobile AQI Unit in the Georgian Bay area were compared to concentrations in the Toronto area.

Since the Parry Sound site operated throughout the 2001 smog season, May 1 to September 30, ozone data collected at this site were compared with concentrations at other rural sites such as Tiverton, Grand Bend and Long Point (as shown in Figure 2). All of the sites studied were similar in that they were strongly affected by the trans-boundary flow of ozone and its precursors from the U.S. Midwest.

Figure 2: Fixed Air Monitoring Stations Used in Study



ANALYSIS OF DATA

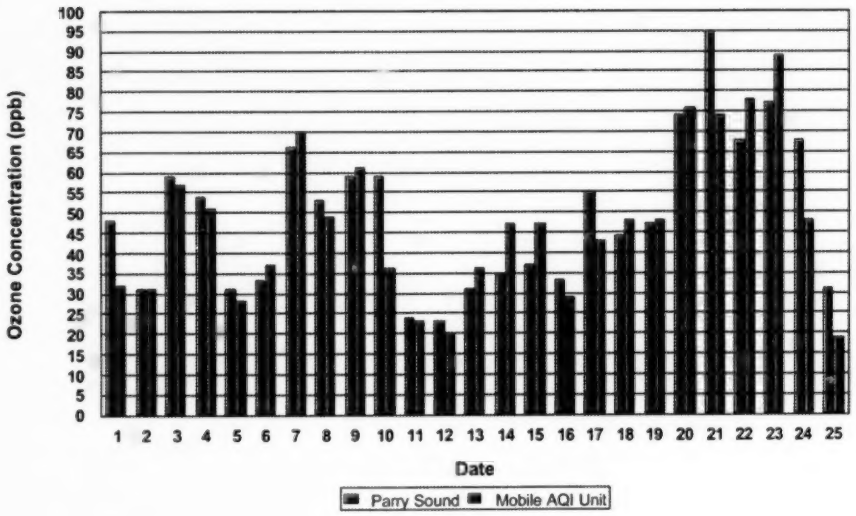
The purpose of correlation analyses is to show if there is any relationship between data sets. As such, a correlation study was carried out between the ozone data collected by the Mobile AQI Unit and the fixed air monitoring site at Parry Sound for the study period July 1 to July 25, 2001. The 24-hour averaged $PM_{2.5}$ data from the Mobile AQI Unit were also correlated with similar data sets from Tiverton and Dorset. Measurements of O_3, PM_{25}, NO_2, SO_2, CO and Hg taken by the Mobile AQI Unit were compared to those at Toronto sites during the study period as well. In addition, during the 2001 smog season, May 1 to September 30, the daily maximum 1-hour ozone concentrations measured at Parry Sound were compared with those measured at Tiverton, Grand Bend and Long Point, using histograms and percentiles.

STUDY PERIOD: JULY 1 TO JULY 25, 2002

Comparison of Daily Maximum 1-Hour Ozone Concentrations Between the Mobile AQI Unit and the Parry Sound Air Monitoring Site

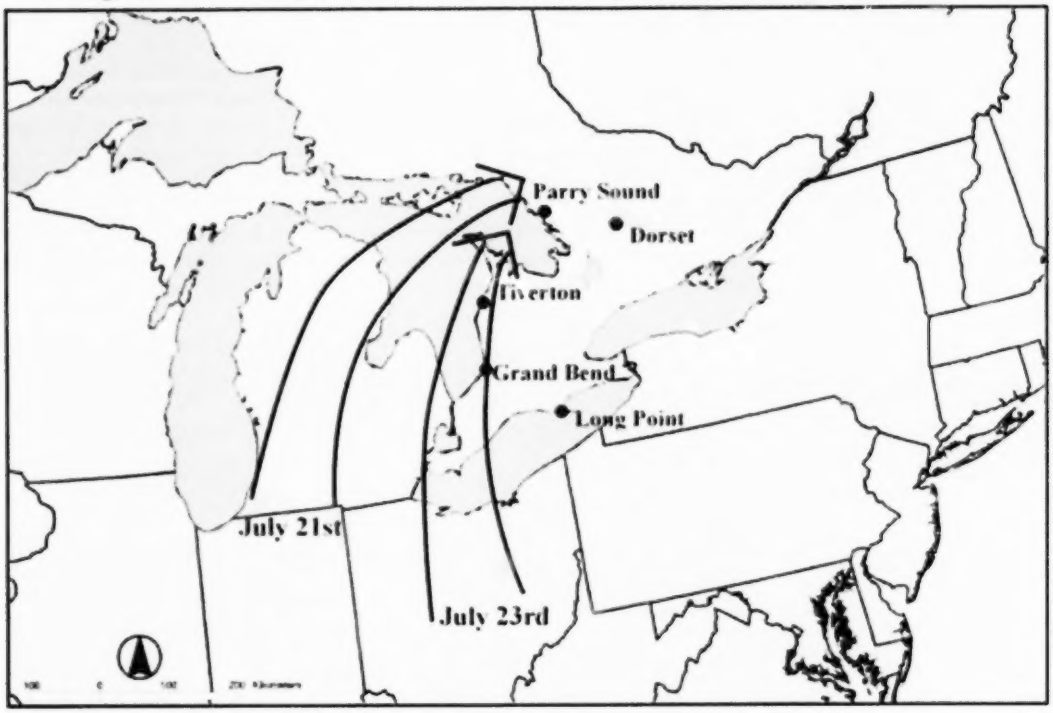
In Figure 3, the daily 1-hour maximum ozone concentrations for the Mobile AQI Unit were compared with the maximum ozone concentrations measured at the Parry Sound AQI station, for the period July 1 to July 25, 2001. The data show there are no significant differences between the concentrations. Neither site continuously measured higher concentrations than the other. There was a very high linear correlation coefficient of 0.86 between the daily 1-hour maximum ozone concentrations measured by the Mobile AQI Unit and those measured at the Parry Sound site. This indicates that ozone concentrations measured at the Parry Sound AQI site are representative of concentrations across the Georgian Bay area.

Figure 3: Maximum Daily 1-Hour Ozone Concentrations
July 1 - 25, 2001



The highest daily 1-hour maximum ozone concentration recorded at the Parry Sound AQI site was 95 parts per billion (ppb) on July 21, 2001. The highest value for the Mobile AQI Unit was 89 ppb on July 23, 2001, when it was located at the Bruce Peninsula National Park. Both values were above the 1-hour provincial AAQC of 80 ppb for ozone. Figure 4 shows the air flow into the Georgian Bay area on July 21 and July 23. The flow was primarily from the U.S. through the state of Michigan on July 21 and through the state of Ohio on July 23. This indicates that the ozone was transported into the area from the U.S. Maximum air temperatures during the three-day period ranged from 28°C to 30°C. The Ministry issued smog advisories on both July 21 and July 23, 2001.

Figure 4: Wind Trajectories into Georgian Bay for July 21 and July 23, 2001



Comparison of Daily 24-Hour Average PM_{25} Concentrations Between the Mobile AQI Unit, Dorset and Tiverton Sites

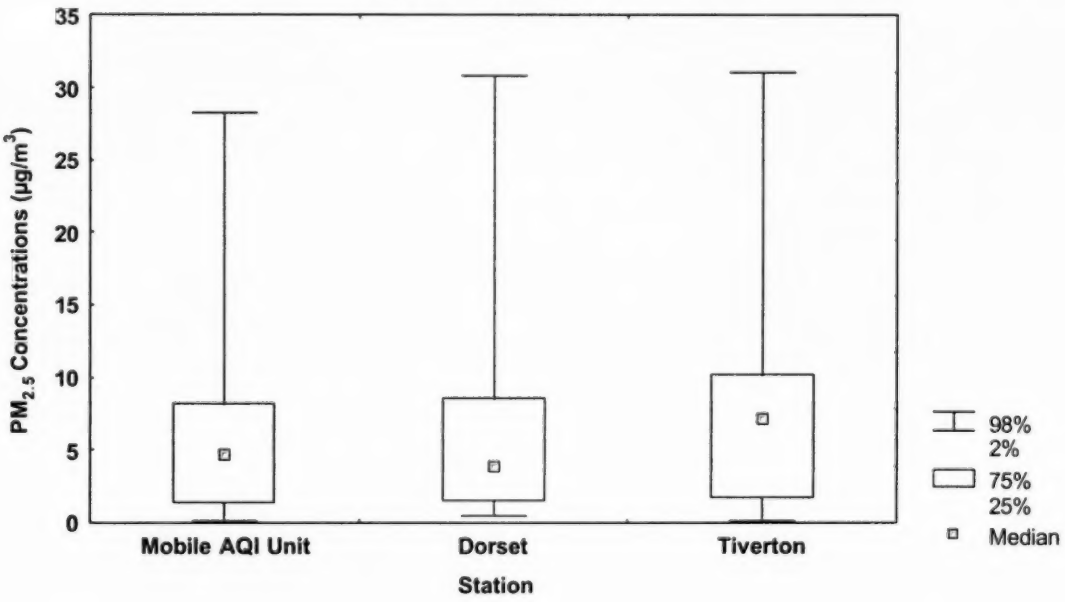
The Parry Sound AQI site does not record measurements of PM_{25}. Daily concentrations of PM_{25} measured by the Mobile AQI Unit in the Georgian Bay area were compared with levels recorded at Dorset and Tiverton July 1 to July 25, 2001. The Dorset AQI site is east of Georgian Bay and the Tiverton AQI site is located southwest of the area (as shown in Figure 2). The comparison of the concentrations recorded by the Mobile AQI Unit and the two fixed AQI sites shows a good representation of the PM_{25} concentrations to which residents in the Georgian Bay area are exposed. It is assumed that on most days these locations are in the same air mass.

Linear correlation coefficients between the various monitoring sites are shown in Table 1. The correlation coefficients between the sites are very high, indicating a strong relationship between the measured concentrations. However, the box plots shown in Figure 5 indicate the concentrations measured at Dorset and the Mobile AQI Unit were similar, in contrast to the higher levels at Tiverton. This suggests that the measurements at Dorset are more representative of concentrations recorded in the Georgian Bay area.

Table 1: Linear Correlation Coefficients of 24-Hour Average Concentrations of $PM_{2.5}$ Between the Mobile AQI Unit, Dorset and Tiverton

Monitor	Location Compared	Linear Correlation Coefficient
Mobile AQI Unit	Dorset	0.96
Mobile AQI Unit	Tiverton	0.97
Tiverton	Dorset	0.94

Figure 5: Box Plots Comparing Percentiles of $PM_{2.5}$ Levels Measured by the Mobile AQI Unit with Dorset and Tiverton July 1 - July 25, 2001



The highest 24-hour average PM_{25} concentration was recorded on July 21, 2001. The measurements were 31.1 micrograms per cubic metre ($\mu g/m^3$), 30.8 $\mu g/m^3$, and 28.2 $\mu g/m^3$ for Tiverton, Dorset, and the Mobile AQI Unit, respectively. The recorded concentrations were very similar (within 90 per cent) of those recorded at the other sites. Since the correlation coefficients were very high and the concentrations were similar, it can be concluded that PM_{25} measurements were approximately the same, particularly during episodes of elevated PM_{25} levels.

Comparison of Various Pollutant Concentrations Between the Mobile AQI Unit and Toronto Sites

The maximum hourly average concentrations of O_3, PM_{25}, NO_2, SO_2, CO and Hg recorded at Toronto and by the Mobile AQI Unit during the period July 1 to July 25, 2001 are shown in Table 2. In the Toronto area, all measurements were recorded at the Toronto Downtown site except for the Hg measurement, which was recorded at the Toronto West site.

The maximum ozone concentration during this period recorded by the Mobile AQI Unit was 10 ppb higher than the maximum at Toronto Downtown. Generally, ozone is lower in urban areas because it is removed by reaction with nitric oxides emitted locally by vehicles. The maximums for NO_2, CO and Hg were significantly higher in the Toronto area than in the Georgian Bay area, reflecting the impact of urban sources of these pollutants. PM_{25} measurements were comparable. The relatively high SO_2 concentration recorded by the Mobile AQI Unit was measured on July 15 at Bruce Peninsula National Park, a day when the air flow was northerly. The original source of the SO_2 was most likely from the Sudbury area.

Table 2: Comparison of Maximum Hourly Concentrations of Pollutants from the Mobile AQI Unit and the Toronto Area

Stations	O_3 (ppb)	PM_{25} ($\mu g/m^3$)	NO_2 (ppb)	SO_2 (ppb)	CO (ppm)	Hg (ng/m^3)
Mobile AQI Unit	89.0	32.0	4.4	30.0	0.74	1.9
Toronto	79.0	30.0	71.0	19.0	2.20	5.9

Note: CO and Hg concentrations are reported in parts per million (ppm) and nanograms per cubic metre (ng/m^3), respectively.

SMOG SEASON: MAY 1 TO SEPTEMBER 30, 2001

Ozone Measurements at Sites Bordering Lake Huron, Lake Erie and the Parry Sound Site

Ozone concentrations recorded at the Parry Sound AQI site were also compared to the ozone concentrations recorded at the Long Point, Tiverton, and Grand Bend AQI sites. The Tiverton and Grand Bend sites are located on the eastern shore of Lake Huron, and Long Point is located on the northern shore of Lake Erie. The comparison of ozone concentrations between these locations, for the 2001 smog season, provides some perspective on the concentration levels recorded at Parry Sound.

Histograms of the daily maximum concentrations of ozone measured at the Parry Sound, Tiverton, Grand Bend and Long Point AQI sites during the period May 1 to September 30, 2001 are shown in Figures 6(a), 6(b), 6(c) and 6(d), respectively. The histograms show that the modal class[1] (35 - 44 ppb) at Parry Sound was 10 ppb lower than the corresponding modal classes at the other sites. This is an indicator that ozone levels, on average, are lower in Parry Sound than at the other sites.

1 *The most frequent values of a data set appear in a modal class.*

Figure 6a: Histogram of Maximum Daily 1-Hour Ozone Concentrations at Parry Sound

May 1 - September 30, 2001

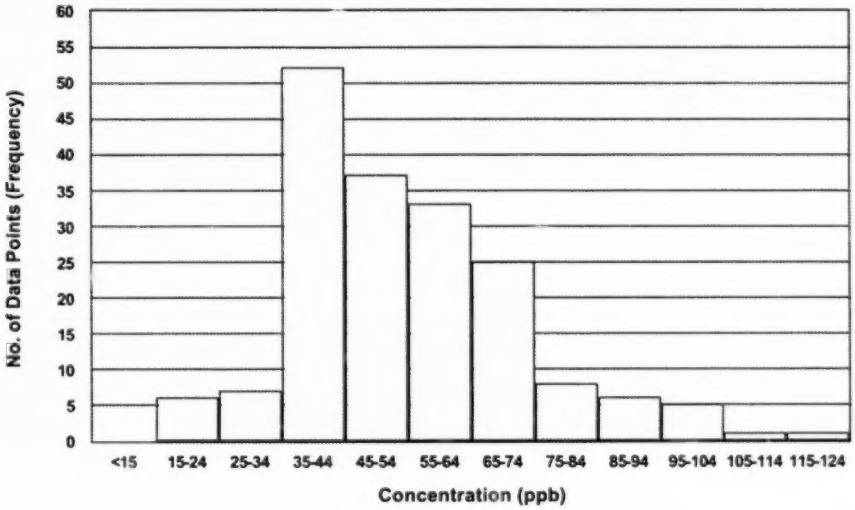


Figure 6b: Histogram of Maximum Daily 1-Hour Ozone Concentrations at Tiverton

May 1 - September 30, 2001

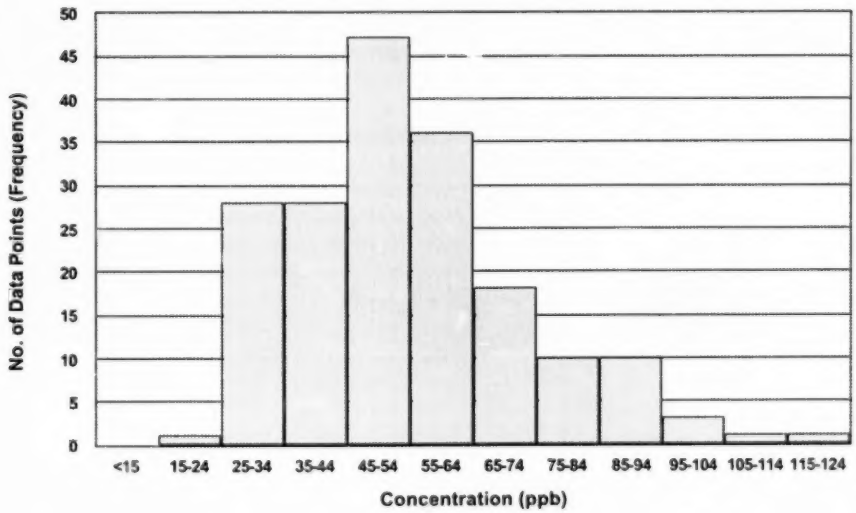


Figure 6c: Histogram of Maximum Daily 1-Hour Ozone Concentrations at Grand Bend

May 1 - September 30, 2001

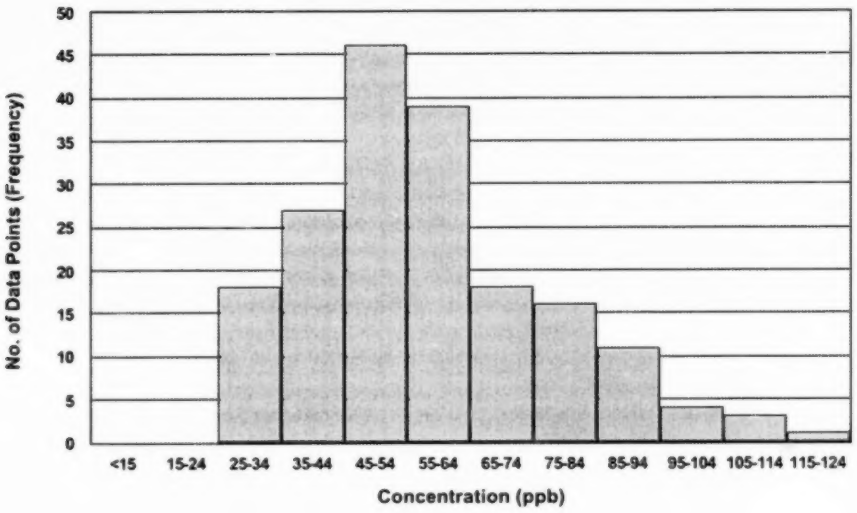


Figure 6d: Histogram of Maximum Daily 1-Hour Ozone Concentrations at Long Point

May 1 - September 30, 2001

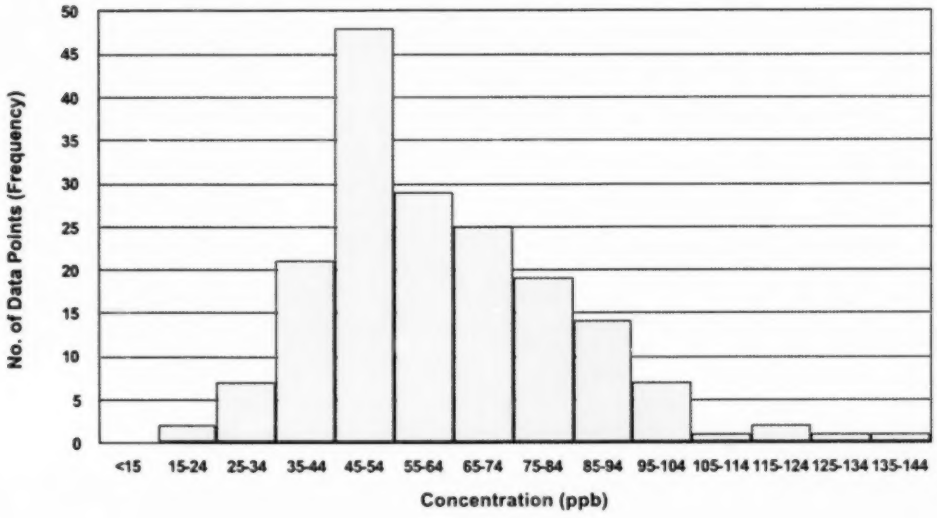


Table 3 shows the percentile distributions of the daily maximum 1-hour ozone concentrations at the four sites.

Table 3: Summary Statistics of Daily Maximum Hourly Ozone Concentrations at Selected Air Monitoring Sites During 2001 Smog Season

Monitoring Station	Minimum	25th percentile	50th percentile	75th percentile	98th percentile	Maximum
Parry Sound	17.0	38.0	52.0	65.0	97.6	116.0
Tiverton	24.0	41.0	52.0	64.0	98.4	116.0
Grand Bend	28.0	45.0	55.0	66.5	103.4	117.0
Long Point	18.0	48.0	59.0	75.0	114.5	137.0

Note: Concentrations are reported in ppb.

The 50th percentiles[2] at Parry Sound and Tiverton were both equal to 52 ppb. The 98th percentiles and maximum concentrations were also equal. Similar percentiles at Grand Bend and Long Point were higher than the values measured at Parry Sound. The maximum 1-hour average ozone concentrations recorded at the sites were as follows: Parry Sound (116 ppb), Tiverton (116 ppb), Grand Bend (117 ppb), and Long Point (137 ppb). The number of days that the 1-hour Ontario AAQC for ozone was exceeded at the sites were: 15 days at Parry Sound, 16 days at Tiverton, 23 days at Grand Bend, and 34 days at Long Point. The elevated measurements at Long Point and Grand Bend are partly due to their closer proximity to the Ohio Valley. The impact of long-range transport of pollution on Long Point and Grand Bend is greater. During the smog season of 2001, there were 17 smog advisory days called for the Tiverton and Parry Sound areas, 21 for the Grand Bend area and 22 for Long Point.

On occasion, however, Parry Sound can record higher maximum levels than the other sites. For example, July 21, 2001 was one such occasion when the Parry Sound site recorded a maximum 1-hour average ozone concentration of 95 ppb. Grand Bend and Tiverton sites recorded 75 ppb and 76 ppb, respectively. This was due to long-range transport of ozone into the Georgian Bay area from the U.S., as shown in Figure 4.

CONCLUSION

The high correlation coefficients between ozone data collected by the Mobile AQI Unit and the Parry Sound site, during the period of July 1to July 25, 2001, suggests that ozone concentrations measured at the Parry Sound monitoring site are representative of measurements across the Georgian Bay area. The results also indicate that PM_{25} measurements at Dorset are representative of PM_{25} measurements to which residents in the Georgian Bay are exposed, particularly during periods of elevated levels of PM_{25} when there is long-range transport of fine particulate matter into the area. The maximums for NO_2, CO and Hg were significantly higher in the Toronto area than in the Georgian Bay area, reflecting the impact of local sources of these pollutants. The comparison of sites which are impacted by long-range transport of pollution from the U.S. showed that ozone concentrations at the Long Point and Grand Bend sites receive higher concentrations of ozone than the Parry Sound site, due to their closer proximity to U.S. sources. However, there are occasions when levels can be higher in the Georgian Bay area than the traditional areas to the south, for example, when the polluted air enters the region directly from upper Michigan and crosses Lake Huron.

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2 *A percentile is the percentage of the data set that lies below the stated value.*